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ENGINEERING APPLICATION AND ECONOMICS OF LIMB

by

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16. ABSTRACT The paper describes the use of an EPA LIMB cost model, in conjunction with cost and performance models for flue gas desulfurization (FGD), to compare these two technologies under similar premises. (NOTE: The performance goals of LIMB, EPA's acronym for Limestone Injection/Multistage Burners for use in SO2/NOx control for coal-fired boilers, are 50-60% reduction of SO2 and NOx for retrofit systems, and achievement of New Source Performance Standards (NSPS) for SO2 and NOx for application on new utility boilers. These performance requirements, furthermore, are to be achieved at significantly lower cost than that for FGD, the major control technology alternative.) For a new 500 MW unit burning 1.92% S coal and achieving control to meet NSPS, costs per ton of SO2 removed are estimated to be $1377, $771, and $921 for limestone FGD, lime spray drying, and LIMB using calcitic hydrate, respectively. At 0.48% S in the coal, these costs are estimated at $3715, $1954, and $1134 for limestone FGD, lime spray drying, and LIMB, respectively. For a 300 MW retrofit system, costs per ton of SO2 removed for wet limestone FGD and LIMB using calcitic hydrate on a 1.92% S coal application are $1359 and $844, respectively.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Nitrogen Oxides	Stationary Sources	14G
Utilization	Limestone Injection/	05C
Economics	Multistage Burners	21D
Coal	Engineering Application	21B
Combustion		08G
Limestone		07B
Sulfur Dioxide		

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ABSTRACT

LIMB is EPA's acronym for Limestone Injection with Multistage Burners for use in SO_2/NO_x control for coal-fired boilers. LIMB performance goals are 50 to 60% reduction of SO_2 and NO_x for retrofit systems, and achievement of New Source Performance Standards (NSPS) for SO_2 and NO_x for application on new utility boilers. These performance requirements, furthermore, are to be achieved at significantly lower cost than that for flue gas desulfurization (FGD), the major control technology alternative.

A LIMB cost model was developed by EPA's Air and Energy Engineering Research Laboratory (AEERL) to study and estimate LIMB costs under a variety of assumptions and conditions. This model is used in conjunction with cost and performance models for FGD to compare these two technologies under similar premises. For a new 500 MW unit burning 1.92% S coal and achieving control to meet NSPS, costs per ton* of SO_2 removed are estimated to be $1377, $771, and $921 for limestone FGD, lime spray drying, and LIMB using calcitic hydrate, respectively. At 0.48% S in the coal, these costs are estimated at $3715, $1954, and $1134 for limestone FGD, lime spray drying and LIMB, respectively. For a 300 MW retrofit system, costs per ton of SO_2 removed for wet limestone FGD and LIMB using calcitic hydrate on a 1.92% S coal application are $1359 and $844, respectively. For the same retrofit cases on a 3.36% S coal application, the costs per ton of SO_2 removed for wet FGD and LIMB are $829 and $691, respectively. For the retrofit cases, the FGD systems are costed to meet NSPS, but the LIMB systems are costed at 62% SO_2 control. Bases for economic premises are taken primarily from the EPRI Technical Assessment Guide (TAG™).

* For those more familiar with metric units, see conversions at the end of the paper.

INTRODUCTION

LIMB is EPA's acronym for Limestone Injection with Multistage Burners. When fully developed, it is expected to be a cost-effective emissions control technology for coal-fired boilers that can reduce both sulfur oxides (SO_x) and nitrogen oxides (NO_x). The LIMB concept uses low-NO_x burners plus sorbent injection to simultaneously control these pollutants.

LIMB technology is especially attractive where coal-fired boilers must be retrofit to minimize emissions of NO_x and SO_x, which are major acid rain precursors. This is due to LIMB's relative ease of retrofit to both small and large coal-fired boilers and its lower cost. LIMB performance goals are to achieve a 50 to 60% reduction of both SO_x and NO_x from uncontrolled levels for retrofit, and to achieve a 70 to 80% reduction of NO_x and 70 to 90% reduction of SO_x from uncontrolled levels for new units.(1)

EPA's LIMB cost modeling activities are a response to a need for making rapid and accurate comparative economic assessments of LIMB technology with other SO_2 control approaches such as flue gas desulfurization (FGD). This work was initiated in May 1984 with the development of the LIMB cost model described in this paper. Our ability to conduct comparative economic studies has subsequently been augmented by incorporation of cost models for FGD and integrated air pollution control systems that were developed under earlier EPA contracts. A broad base of cost data for NO_x, SO_x, and particulates resides within EPA's Air and Energy Engineering Research Laboratory at Research Triangle Park.

TECHNOLOGY BACKGROUND

The use of sorbents injected into boilers to control emissions of SO_x from coal-fired power plants is not a new concept. It was evaluated most extensively during the period of 1968 to 1971. Recently, the potential of the sorbent injection (LIMB) process has been re-examined principally because of 1) a need to develop low cost SO_2 control technology for acid rain control strategies, 2) pilot-scale tests that indicated that significantly higher SO_2 capture could be achieved at reasonable alkali to sulfur ratios, and 3) an improved understanding of the critical process variables that affect sorbent performance.

COMPARISON OF LIMB AND FGD COST ESTIMATING METHODOLOGIES

Process economics like most other quantifiable items is relative; the numbers mean less in an absolute sense but are very meaningful when they are used to compare two or more processes with each other. Since FGD processes are currently the predominant SO_2 controls used for fossil-fueled utility boilers, comparisons between projected LIMB costs and FGD costs were deemed appropriate to investigate the potential economic viability of LIMB. LIMB and FGD costs should be compared with proper perspective. Since FGD is a relatively mature technology, the projected costs are backed by

actual full scale applications experience; whereas, LIMB is a relatively new technology, and its projected costs are based on pilot data. The accuracy of the FGD costs is expected to be in the range of -15%, +30%; accuracy of the LIMB costs is expected to be somewhat less.

The EPA LIMB cost model was developed in-house at AEERL at Research Triangle Park, N.C. The computer program was developed using BASIC language on a Zenith 100 microcomputer. The program and imbedded comments contain approximately 1000 lines of code and, when the optional printed reports are produced, a typical session and associated case study takes less than 3 minutes to complete.

The program is designed for minimum user input of LIMB system operating and performance data and generates corresponding material balances, solids distribution, emissions summary, tons/year SO_2 removed at given capacity factor, detailed capital requirement, operating and maintenance costs, first year costs, levelized costs, and cost per ton SO_2 removed.[2]

Since EPA's LIMB cost model was developed with a high degree of flexibility, an FGD model with a similar degree of flexibility was sought for comparative studies. Fortunately, TVA developed just such a model (called the Computerized Shawnee Lime/Limestone (L/LS) Scrubbing Model) under an interagency agreement with EPA. This model accepts about 150 user input variables and about 20 print control variables and is considered a preliminary design and cost model for wet lime and limestone FGD processes.

The TVA Shawnee L/LS model is a design and cost model for new wet FGD control systems. To project costs of retrofit systems, a program was written for a TI-59 hand-held calculator to use the results of the TVA program to project the cost of retrofit systems. The basic assumption used was that the total capital investment would increase by 30% over that for a new system. The program calculates revised annualized costs by increasing total capital investment and those items that are estimated as a function of capital, but keeps constant items such as labor and unit costs which are not dependent on total capital investment. The FGD retrofit results are based on this program.

Currently, TVA is developing a design and cost model for new lime spray drying (LSD) dry FGD systems. This model, with 100 user input variables and 23 print control variables, is very similar to the Shawnee L/LS scrubbing model. Although this model is still under development, it is sufficiently developed to produce preliminary results, which are given in this paper. The reader is cautioned that these results should be treated as preliminary at this time, and understand that they may change when the model development is complete.

The TVA LSD cost model produces a design and cost for a new LSD system including the cost of a fabric filter.

Since the fabric filter collects both particulate matter from the boiler and spent sorbent from the LSD process, its cost cannot be attributed only to SO_2 control. In order to compare costs for LSD with those of wet FGD and LIMB, on a common basis, the costs of the fabric filter and its operation and maintenance were deducted from the output of the model, and then appropriate adjustments were made to the indirect costs.

For purposes of this paper, LIMB is compared to LSD only for new units burning low and medium sulfur coal.

COMPARATIVE COSTS OF SO_2 CONTROL TECHNOLOGIES

LIMB technology offers economic advantages over conventional FGD methods when moderate SO_2 control levels (45 to 65%) are required. The costs of these SO_2 control technologies have recently been evaluated in considerable detail by EPA, based on work conducted by TVA[3], Combustion Engineering, Inc.[4], PEI Associates, Inc., [5], and in-house cost analysis work at AEERL.[2]

Since the SO_2 removal efficiencies are different for LIMB and FGD, cost comparisons are presented on a unit cost or normalized basis; i.e., cost per ton of SO_2 removal. The cost analysis procedures are based to the maximum extent possible on guidelines suggested by the Electric Power Research Institute [6]. The current dollar analysis method is used with costs expressed in 1985 dollars. For retrofit units, 15-year levelized costs are used; whereas, 30-year levelized costs are used for new units. Internally consistent costs and/or factors for such items as operating and maintenance labor, maintenance material, administrative and support labor, consumables, and levelization factors have been employed to ensure that the LIMB and FGD costs are on an equivalent basis. It is beyond the scope of this paper to discuss these in any depth, but we have ensured that most charges and assumptions are consistent within and between LIMB and FGD.

Some of the technology-related assumptions used in developing the costs for LIMB are:

a. New units are assumed to be already equipped with burners capable of meeting the current NO_2 standard of 0.6 $lb/10^6$ Btu for bituminous coal and 0.5 $lb/10^6$ Btu for subbituminous coal.

b. Retrofit units are assumed to be installed with improved burners capable of meeting NO_2 emissions of 0.7 $lb/10^6$ Btu.

c. New units are assumed to be already equipped with a bare-tube economizer.

d. Retrofit units are assumed to have an existing finned-tube economizer which is replaced with a bare-tube economizer.

e. Retrofit units have upgraded ESPs to handle the additional solids loading plus SO_3 conditioning to improve resistivity.

f. New units have baghouses which are not charged off as a LIMB-related cost.

g. Both new and retrofit units have sootblower upgrades, a sorbent injection system, and dry waste disposal.

Some of the technology-related assumptions used in developing wet FGD costs are:

a. Spray tower absorbers using limestone slurry and forced oxidation were specified.

b. Waste disposal is by landfill.

c. One spare absorber was specified for new units, and no spares for retrofit cases.

d. Emergency by-pass of 50% of the flue gas normally scrubbed is provided.

e. Reheat is by in-line steam tube reheater to 175°F.

Some of the technology-related assumptions used in the LSD cost model are:

a. Waste disposal by landfill.

b. Reheat to 170°F by warm untreated flue gas by-pass from the air heater or by hot untreated flue gas from the economizer, whichever is necessary to achieve reheat to the desired temperature without exceeding NSPS requirements.

c. Spray dryer approach to saturation of 18F°.

d. For a new 500 MW unit, three operating spray dryers plus one spare, and one redundant feed preparation system.

e. Lime inerts are removed with a classifier and taken to disposal.

For wet FGD systems, the stoichiometric ratio is defined as the moles of calcium per mole of SO_2 absorbed. For LIMB, the stoichiometric ratio is defined as moles of calcium per mole of sulfur in the fuel. Typically, a stoichiometric ratio of 1.4 is used with wet FGD for 90% SO_2 control; whereas, for LIMB, stoichiometric ratios of 1.4 to 2.5 might be employed depending on the sorbent and required control level. A LIMB system using a Ca/S

ratio of 2 and achieving 50% SO_2 control would be equivalent to a stoichiometric ratio of about 4 using FGD's nomenclature for stoichiometric ratio. The LSD model calculates a required stoichiometric ratio and expresses it in moles of Ca per mole S in the boiler flue gas. The calculated stoichiometric ratios for the cases presented in this paper are 0.888 and 1.032 moles Ca/mole S in the boiler flue gas for the 0.48% S and 1.92% S cases, respectively. The figures in this paper that illustrate the comparative costs of LIMB and FGD use the stoichiometric ratio nomenclature associated with the respective technology. For LIMB, it is shown as Ca/S; for FGD, it is shown as Ca/SO_2.

Table 1 gives the boiler and coal characteristics used for the economic analysis presented in this paper. The unit sizes selected represent those typical of retrofit and new applications. Wall-fired designs were used in all cases. The coals encompass the sulfur content range targeted for application of these SO_2 control technologies. The net plant heat rate is used in the analysis to determine the required coal flow and corresponding S and SO_2 mass flow rates.

Table 1

BOILER AND COAL CHARACTERISTICS SELECTED
FOR LIMB AND FGD ECONOMIC ANALYSIS

			Coal Characteristics	
Unit Size, MWe	Status	Net Plant Heat Rate, Btu/kW•h	High Heating Value, Btu/lb	% S
300	Retrofit	9,500	11,700	3.36
300	Retrofit	9,500	11,700	1.92
500	New	9,500	11,700	1.92
500	New	10,500	8,200	0.48

NOTE: Wall-fired boilers are used in these case studies.

Table 2 gives the sorbents, Ca/S ratios, and SO_2 control levels used in the LIMB economic analysis. The performance data are derived from pilot scale tests shown in Figure 1 and from in-house testing of sorbents with promoters. Promoted sorbents contain relatively small amounts of mineral substances that are added to enhance the sulfur capture potential of the sorbent. Some very preliminary work conducted to date indicates that the use of a promoter such as sodium carbonate can increase $CaCO_3$ and $Ca(OH)_2$ performance by about 1.4 times that typical of the unpromoted sorbent. The sorbent costs represent delivered costs to the power plant based on current estimates from sorbent suppliers. The selection of these specific

Ca/S ratios and corresponding SO_2 control levels resulted from an initial sensitivity and optimization study in which a range of Ca/S ratios and SO_2 control levels were evaluated. The values selected represent the optimum economic levels for these sorbents.

Table 2

SORBENTS AND PERFORMANCE DATA USED FOR LIMB ECONOMIC ANALYSIS

		Retrofit		New	
Sorbent	Sorbent Cost, $/ton	Ca/S	SO_2 Control, %	Ca/S	SO_2 Control, %
Vicron $CaCO_3$	18 [a]	2.5	45	-	-
Longview $Ca(OH)_2$	45	2.0	62	2.7	70
Longview $Ca(OH)_2$	45	-	-	4.0	82
Corson $Ca(OH)_2 \cdot Mg(OH)_2$	60	1.4	62	1.63	70 [b]
Corson $Ca(OH)_2 \cdot Mg(OH)_2$	60	-	-	2.1	82 [c]
Promoted $CaCO_3$	25	2.0	56	-	-
Promoted $Ca(OH)_2$	50	1.5	65	1.8	70 [b]
Promoted $Ca(OH)_2$	50	-	-	2.8	82 [c]

a Actual cost used was $17.88/ton.

b Minimum percent control required by NSPS for the 0.48% S coal.

c Minimum percent control required by NSPS for the 1.92% S coal to be at or below 260 ng/J (0.6 lb/10^6 Btu).

For retrofit units, the Ca/S ratio sets the SO_2 control level. For new units, required SO_2 control levels to meet New Source Performance Standards were determined for the coals being used, which in turn set the Ca/S ratios.

Figure 2 and Table 3 present the results of the economic analysis of LIMB and FGD for retrofits. Note that for intermediate sulfur levels (e.g., 1.92%), LIMB is consistently more cost effective than wet FGD in the categories of cost per ton of SO_2 removed, total capital requirements, and levelized revenue requirements. For higher sulfur levels (e.g., 3.36%), wet FGD has a slight edge in terms of cost per ton of SO_2 removed over LIMB when limestone and/or pressure-hydrated dolomitic lime is used as the LIMB sorbent. This is due in part to the scenario chosen for wet FGD in that FGD would be retrofit to meet NSPS requirements. For

FGD, the differential cost in capital requirement and levelized revenue requirement that occurs in going from 1.92 to 3.36% sulfur is offset to an extent by the increased SO_2 control. For LIMB cases, a constant percentage control is assumed for these coals; consequently, on a cost per ton of SO_2 removed basis, LIMB's cost advantage relative to wet FGD diminishes for limestone or pressure-hydrated dolomitic lime. However, LIMB continues to exhibit an economic advantage when $Ca(OH)_2$, promoted $Ca(OH)_2$, or promoted $CaCO_3$ is used as the sorbent. Note also, that LIMB consistently shows an advantage over FGD in terms of total capital requirement and is always more than $100/kW cheaper.

Figure 3 and Table 4 present the results of the economic analysis of LIMB, LSD, and wet FGD for new units meeting NSPS. With low sulfur coal (0.48% sulfur), LIMB exhibits a significant economic advantage over wet FGD and a somewhat less but still significant advantage over LSD in terms of unit cost of SO_2 removal, levelized annual revenue requirements, and capital cost. With intermediate sulfur coal (1.92% sulfur), LIMB continues to show economic advantage over wet FGD, but is evaluated to be about equal to LSD in terms of unit cost of SO_2 removal and annual revenue requirements. LIMB still has a lower total capital requirement than both wet FGD and LSD. For LIMB, the cost per ton of SO_2 removed is affected significantly by sorbent cost as reflected in the line representing the pressure hydrated dolomitic lime. $Ca(OH)_2$, both unpromoted and promoted, appears to be the sorbent of choice for NSPS applications.

An examination of Tables 3 and 4 shows that all three processes are O&M intensive; but, as a percentage of the total levelized revenue requirements, LIMB is more O&M intensive. This results because of lower sorbent cost and somewhat more favorable sorbent utilization with wet FGD and LSD. Despite this, LIMB has overall cost advantages that appear favorable for many applications.

CONTINUING WORK

LIMB TECHNOLOGY DEVELOPMENT

Various LIMB concepts have been tested at the bench and pilot scales to date, in experimental facilities ranging up to 100 million Btu/hr. Research activities have dealt with and will continue to explore basic chemistry, sorbent type and activity, fuel interactions, boiler design parameters, reaction kinetics, and various aspects of these broad general areas. These activities all support, ultimately, a demonstration of the technology at a full scale power plant. Plans for the first such demonstration in the United States are underway for the retrofit of a 105 MW wall-fired boiler at the Edgewater Plant of Ohio Edison which is expected to start operation in 1987.

COMPARATIVE ECONOMICS

In order to continue economic evaluations of LIMB processes and to evaluate them relative to other competing technologies,

plans are underway to modify and update another existing cost and performance model called the Integrated Air Pollution Control System (IAPCS) which was developed by PEI, Inc., under contract with EPA in 1983. The IAPCS was designed to compare the cost and performance of various combinations of nine control technologies used with fossil fueled power plants.

Currently, PEI under contract with AEERL is updating the LIMB, FGD, ESP, and FF modules in the IAPCS. The EPA LIMB cost model will be made a part of the IAPCS, replacing the current (i.e., PEI) LIMB cost module of the model.

The ESP and FF modules will be replaced by programs developed by Viner and Ensor[7] of Research Triangle Institute under contract with EPA in 1982-1983.

The current FGD module in the IAPCS model deals only with wet limestone FGD using a spray tower and forced oxidation. We intend to replace this module with an updated version of the TVA Computerized Shawnee Lime/Limestone Scrubbing Model. This will add a lot of flexibility to consider, for example, lime or limestone, forced or natural oxidation, different waste disposal options, and different scrubber types.

RECYCLE OF SPENT SORBENT

Since LIMB annualized costs and cost per unit pollutant removed are O&M intensive and much of the sorbent remains unused, the potential exists to reduce costs by recycling some of the unused sorbent in the waste. To do this, a process would have to be designed and installed to enrich the spent sorbent in unused reactant and simultaneously produce a waste product poorer in unused reactant. Such a process would require additional capital investment and operating revenue but would balance this cost with a savings in sorbent cost for the overall LIMB process.

Although the LIMB cost model cannot be used to conceive and design such a process, it can be used to determine break-even costs for the installation and operation of the potential process. The LIMB cost model has been modified to consider recovery and recycle. The user must supply inputs concerning the enrichment of the waste and the percent recycle. The cost model will then be used to help guide a preliminary engineering study of potential recycle schemes, rejecting from further study those not economically viable.

SENSITIVITY ANALYSIS AND BY-PRODUCT CREDIT

The model is expected to be used extensively in studying many economic aspects of LIMB processes to help guide the expenditure of resources in basic research and engineering studies so that these resources will be spent where there is the most potential for practical application.

Sensitivity analyses based on the model may be used to examine the effects of such items as by-product credit, sorbent cost, capacity factor, and stoichiometry on the process economics for a range of applications. By-product credit is of particular interest because the LIMB processes will produce greater quantities of waste (dry basis) than the currently used SO_2 control technologies. As more is learned about the LIMB process and its wastes, beneficial utilization techniques will be sought and further developed if economically viable. LIMB technology has been developed through laboratory, bench, and pilot scale testing to the brink of a large scale demonstration. Comparative economic studies indicate that it has the potential to compete with wet flue gas desulfurization and lime spray drying, the currently accepted technologies, as a cost-effective control technology for SO_2 control from new and existing large coal-fired power plants burning low and medium sulfur coals. Since the acid rain issue is frequently in the news, and a global concern, cost effective solutions are being sought. This technology may provide a means for significantly reducing acid rain precursors at reasonable cost.

CONVERSION UNITS

To convert from	to	Multiply by
$lb/10^6$ Btu	ng/J	433
tons	metric tonnes	0.907
Btu	J	1055
lb	kg	0.454
gal.	liters	3.78
°F	°C	5/9 (°F-32)

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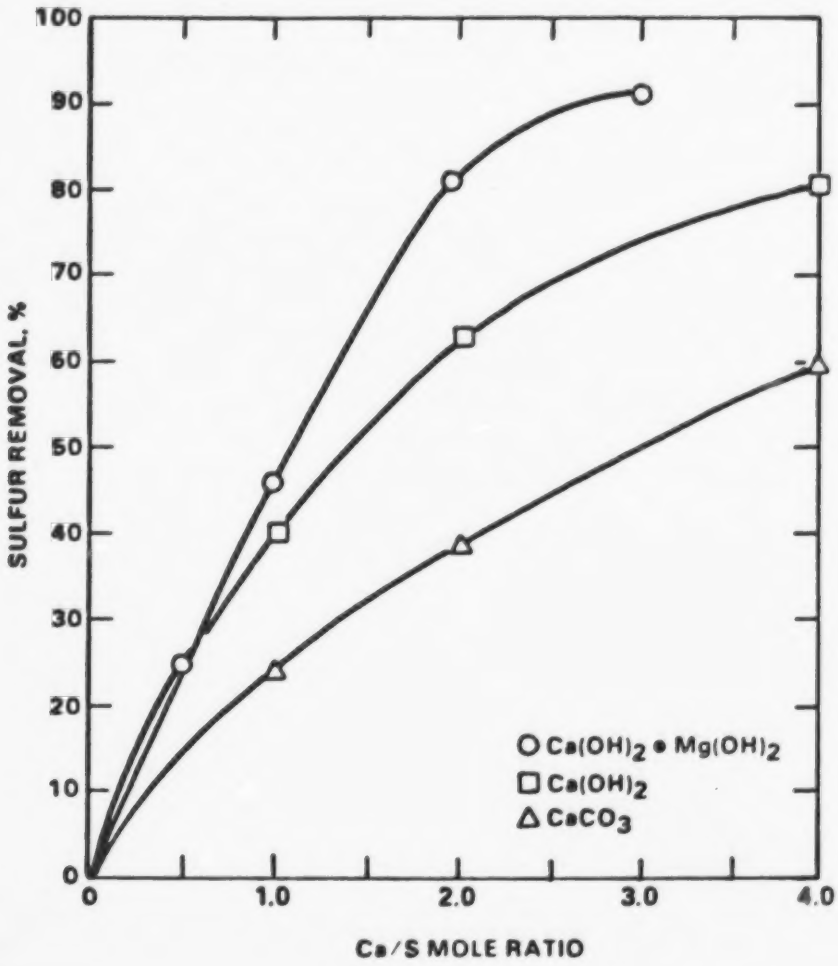

Figure 1. Typical sorbent performance.

(Revised 3/21/85)

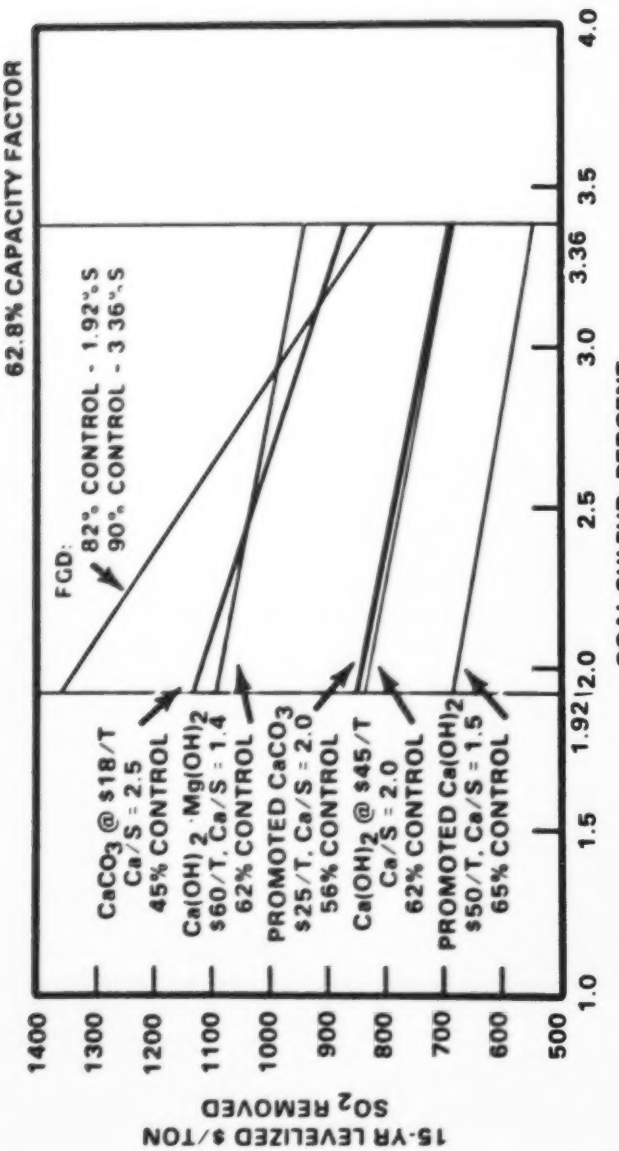

Figure 2. Comparison of SO_2 control technology cost; 300 MWe retrofit.

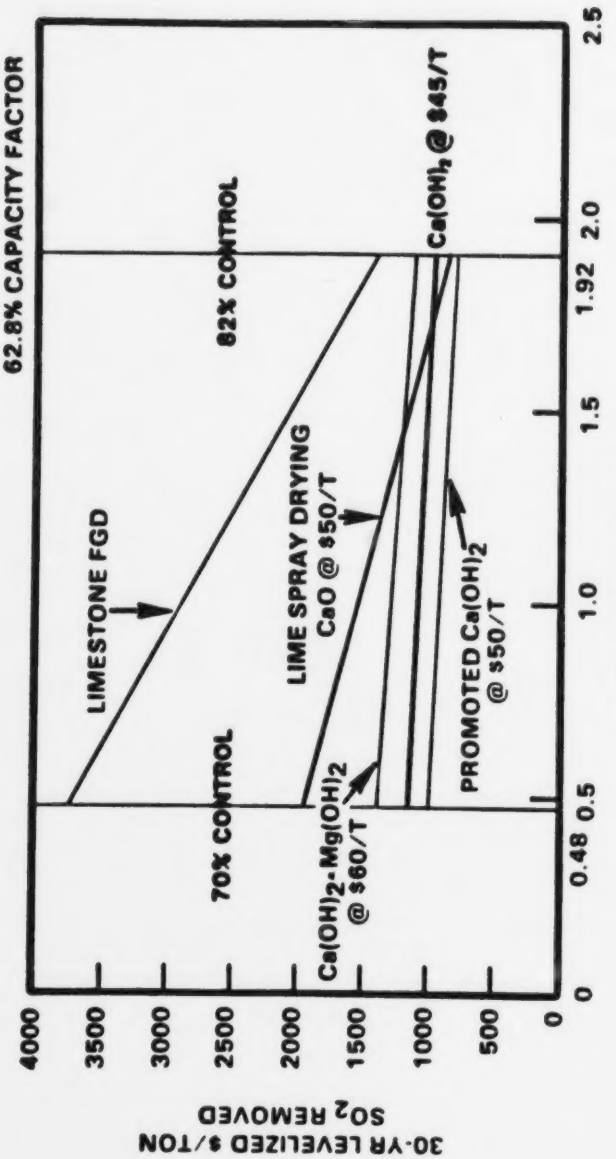

Figure 3. Comparison of SO_2 control technology cost; 500 MWe NSPS.

Table 3

COMPARISON OF COST COMPONENTS FOR RETROFIT LIMB AND FGD
Basis: 300 MWe Wall-fired Units at 62.8% Capacity Factor; 1985 Dollars

Technology	Sulfur, %	Sorbent	SO_2 Removal, $/ton	Total Capital Requirement, $/kW	15-Year Levelized Revenue Requirement, mills/kW•h[a]	15-Year Levelized Capital, mills/kW•h	15-Year Levelized Operating and Maintenance, mills/kW•h
FGD	1.92	$CaCO_3$	1359	210	17.30	6.10	11.20
LIMB	1.92	$CaCO_3$	1135	88	7.99	2.57	5.42
LIMB	1.92	$Ca(OH)_2$	844	79	8.14	2.30	5.84
LIMB	1.92	$Ca(OH)_2 \cdot Mg(OH)_2$	1101	89	10.61	2.59	8.02
LIMB	1.92	$CaCO_3$[b]	855	74	7.47	2.16	5.31
LIMB	1.92	$Ca(OH)_2$[b]	688	64	6.94	1.87	5.07
FGD	3.36	$CaCO_3$	829	239	20.22	6.97	13.25
LIMB	3.36	$CaCO_3$	874	107	10.81	3.11	7.70
LIMB	3.36	$Ca(OH)_2$	691	107	11.64	3.11	8.53
LIMB	3.36	$Ca(OH)_2 \cdot Mg(OH)_2$	942	122	15.87	3.55	12.32
LIMB	3.36	$CaCO_3$[b]	695	102	10.63	2.97	7.66
LIMB	3.36	$Ca(OH)_2$[b]	556	87	9.78	2.54	7.24

a Includes levelized capital and levelized operating and maintenance charges.

b Promoted sorbent.

Table 4

COMPARISON OF COST COMPONENTS FOR NEW LIMB AND FGD
Basis: 500 MWe Wall-fired Units at 62.8% Capacity Factor; 1985 Dollars

Technology	Sulfur %	Sorbent	SO_2 Removal, $/ton	Total Capital Requirement, $/kW	30-Year Levelized Revenue Requirement, mills/kW•h[a]	30-Year Levelized Capital, mills/kW•h	30-Year Levelized Operating and Maintenance, mills/kW•h
Wet FGD	0.48	$CaCO_3$	3715	158	15.97	4.39	11.58
LIMB	0.48	$Ca(OH)_2$	1134	19	4.87	0.54	4.33
LIMB	0.48	$Ca(OH)_2$•$Mg(OH)_2$	1366	21	5.87	0.58	5.29
LIMB	0.48	$Ca(OH)_2$[b]	961	18	4.13	0.49	3.64
LSD[c]	0.48	CaO	1954	117	8.40	3.25	5.15
Wet FGD	1.92	$CaCO_3$	1377	170	17.53	4.73	12.80
LIMB	1.92	$Ca(OH)_2$	921	27	11.77	0.74	11.03
LIMB	1.92	$Ca(OH)_2$•$Mg(OH)_2$	1078	28	13.74	0.79	12.95
LIMB	1.92	$Ca(OH)_2$[b]	761	30	9.69	0.82	8.87
LSD[c]	1.92	CaO	771	116	9.82	3.23	6.59

a Includes levelized capital plus levelized operating maintenance charges.

b Promoted sorbent.

c LSD is an acronym for "Lime Spray Drying." The purchased reagent for LSD is CaO or pebble lime which is slaked on-site and used as a $Ca(OH)_2$ slurry in the LSD process. The LSD results are considered to be preliminary since the cost model upon which they are based is currently under development.